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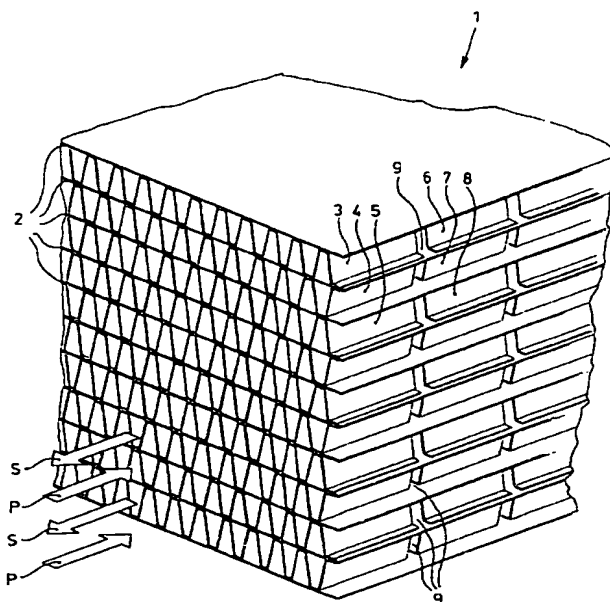
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(54) Title: HEAT EXCHANGER AND METHOD FOR MANUFACTURING THEREOF



(57) Abstract: A heat exchanger (1) comprising two sets of medium through-flow channels (P,S) through which two media can flow in heat-exchanging contact; walls (2) separating the channels; heat conducting fins (3-8) arranged on both sides of each wall (2), wherein a fin on the one side of a wall is in thermal contact with a similar contact surface of a fin on the other side of this wall; wherein the wall (2) are embodied as membrane and the fins (3-8) are embodied as heat transferring strips with a general wave shape and are provided with contact surfaces connected to the walls and main planes extending between two wall.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

HEAT EXCHANGER AND METHOD FOR MANUFACTURING THEREOF

The invention relates to a heat exchanger,
comprising

two sets of medium through-flow channels which are
placed mutually interlaced and through which two media
5 can flow physically separated from each other in a
primary circuit (P) respectively a secondary circuit (S)
and solely in heat-exchanging contact;

walls separating said channels;

heat-conducting fins which are arranged on both
10 sides of each wall, which fins extend with their main
planes in the respective flow directions of said media,
wherein a fin on the one side of a wall, via a contact
surface in the main plane of the wall in question and
forming part of the fin, is in thermal contact with a
15 similar contact surface of a fin on the other side of
this wall;

a housing in which the channel-bounding walls with
the fins are accommodated, to which housing two inlets
and two outlets for the two sets of channels connect
20 either individually per channel or commonly for the sets
of channels via respective manifolds.

Such a heat exchanger is known in many embodiments.
It is an object of the invention to embody a heat
exchanger such that it is very light and can be
25 manufactured inexpensively, while nevertheless still
having an excellent efficiency.

In this respect the heat exchanger according to the
invention has the feature that the walls are embodied as
membranes and the fins are embodied as heat-
30 transferring, for instance metal strips with a general
wave shape, which fins are provided with contact
surfaces connected to the walls and main planes
extending between two walls, this such that, in addition
to a thermal function, the fins also have a structural
35 function, wherein the coefficient of heat transfer of
the whole separating wall amounts to a minimum of 1
W/m²K.

The heat exchanger according to the invention thus derives its mechanical strength and rigidity substantially from the fins. According to the prior art the mechanical strength and rigidity of heat exchangers
5 are not generally determined by fins but by the heat-exchanging walls. This requires the use of mechanically strong and therefore thick walls, which thereby have the inherent drawback of a greater thermal resistance, to the extent the same materials are used.

10 The heat exchanger according to the invention can combine a high efficiency with a very compact construction.

It should be understood that at least in theoretical sense a membrane is an "infinitely thin"
15 skin-like element, which has a negligible bending stiffness and can therefore only derive its stiffness from the fact that it is clamped on its ends, optionally in combination with a certain tensile stress in the form of a bias. When a pressure difference occurs between the
20 primary circuit and the secondary circuit, a certain bending of a practical membrane cannot be wholly prevented. This means that the pressure resistance of a heat exchanger according to the invention is limited to a value determined by the mechanical properties, such as
25 the thickness of the foil used, the tensile strength, the ability to stretch, the limit of stretch, the bias, the mutual distance between the foil layers and the like. When a bias is used, this forms an extra load on the foil material. The maximum tensile stress in the
30 foil is therefore equal to the total maximal tensile stress minus the bias.

In order to make the heat transfer between the layers of fins as great as possible, the embodiment is recommended in which corresponding contact surfaces are
35 in thermal contact via the wall.

In a practical embodiment the heat exchanger has the feature that the contact surfaces are adhered to the wall by means of an adhesive layer applied to at least one contact surface.

40 An alternative has the feature that corresponding contact surfaces are directly connected to each other

via a perforation in the wall by means of an adhesive layer applied to at least one contact surface.

It will be apparent that it is essential that the thermal resistance formed by the foil wall and the glue
5 layer must be as small as possible. In this respect these layers must be thin.

In respect of the thermal contact between adjacent layers of fins, the embodiment is recommended in which the walls consist of PVC and the fins are connected to
10 the walls by an ultrasonic treatment or a thermal treatment, in combination with pressure. The connection can for instance take place by welding, soldering or the like, in any case such that the thermal resistance formed by the foil is absent.

15 A preferred embodiment has the special feature that the housing is form-retaining and the walls are connected to the housing in manner resistant to tensile stress, such that the tensile stresses occurring in the walls as a result of a pressure difference between the
20 two sets of channels can be absorbed by the housing.

Another embodiment has the feature that the walls are biased such that, at a preselected maximum permissible pressure difference between the two sets of medium through-flow channels, the bending of the wall
25 between the free space defined by the contact surfaces of the fins, i.e. the bending of the membrane occurring at the relevant pressure divided by the relevant mutual distance between the contact surfaces in question, amounts to a maximum of 2.5%.

30 In the embodiment in which corresponding contact surfaces are in thermal contact via the foil wall, the heat exchanger preferably has the feature that the thermal resistance of the foil transversely of its main plane amounts to a maximum of 0.1 of the thermal
35 resistance in the case of direct contact between contact surfaces directed toward each other, and is therefore negligible.

The heat exchanger preferably has the feature that the thermal resistance of the foil in its main plane
40 over the mutual distance between two fins adjoining in

flow direction is at least 10 times greater than in the case of fins directly coupled to each other thermally.

A practical embodiment has the special feature that the walls consist of PET, for instance reinforced PET, are treated with a corona discharge, are then provided with a primer, followed by a glue layer for connection to the contact surfaces of the fins.

An alternative embodiment has the feature that the walls consist of PVC and that the fins are connected to the walls by an ultrasonic treatment or a thermal treatment, in combination with pressure.

A substantial improvement in the tensile strength relative to the usual foil materials is obtained with a heat exchanger which has the feature that the foil consists of a fibre-reinforced material, which fibres consist for instance of glass, boron, carbon. The fibres can for instance be embodied as fabric or as non-woven.

A great improvement of the thermal conductivity of the foil is realized with a heat exchanger which has the feature that the walls consist of a plastic in which aluminium powder is embedded.

In order to enable the heat exchanger to be maintenance-free and make it suitable for the most diverse applications, the heat exchanger can have the feature that the walls consist of PET, for instance reinforced PET, are treated with a corona discharge, are then provided with a primer, followed by a glue layer for connection to the contact surfaces of the fins.

A very practical embodiment has the special feature that the walls protrude outside the fins such that they can be connected to a frame, for instance in order to place them under bias, or such that the protruding wall parts can be thermally formed into interlacing units and manifolds for respectively joining together and separating again the sets of channels. This embodiment alleviates the problem of embodying an interlacing unit and manifold on both sides of the heat exchanger.

A determined embodiment has the feature that the heat exchanger is given a modular structure with blocks which can be releasably coupled to each other. Thus is achieved that the heat exchanger can be manufactured in

different dimensions by making use of blocks, without substantial change-over of a production line being necessary for this purpose.

A particular embodiment has the feature that the
5 layers are ordered in the sequence P, S, P, S, P, S and so on.

Another embodiment has the feature that the layers are ordered in the sequence P, P, S, S, P, P and so on.

In order to limit the mechanical load on the foil
10 layers as much as possible during production of the heat exchanger, a preferred embodiment has the special feature that the contact surfaces of the fins have rounded peripheral edges.

In an embodiment in which the foil consists of a
15 fibre-reinforced material, the heat exchanger can have the special feature that the fibres have an anisotropic heat conduction, such as carbon fibres, wherein the heat conduction is smaller in the main plane of the foil than in transverse direction thereof. The tensile strength of
20 the foil strips and thereby the pressure resistance of the heat exchanger is hereby substantially improved, and a very good heat contact between adjacent fins is also achieved.

A suitable choice of the foil materials can be made
25 with an eye to operating conditions and applications. Thermoplastic plastics as well as thermosets such as polyether imide are suitable. The foil materials can also be provided with a coating, for instance of another plastic, a silicon material or the like. In the case of
30 fibre reinforcement the fibres can have diameters of a few μm .

Another choice of material for the membranes is metal, in particular a plastic foil with a metal coating on at least one of the two sides.

35 A very simple solution to a possibly occurring corrosion problem consists of the adhesion having taken place with an anticorrosive coating applied to at least one of the two contact surfaces and for instance comprising a primer layer and/or an adhesive layer
40 extending over the whole surface of the fins and optionally the wall.

A specific embodiment has the special feature that the adhesive layer is of the type which can be thermally activated and that the fins are adhered to the relevant wall and/or to an adjacent set of fins at the position
5 of the contact surfaces by heating and pressure by means of a heated pressing punch.

In yet another variant the heat exchanger has the feature that the fins are provided on the side remote from said coating with a second coating which can
10 withstand said heating and pressure.

The invention will now be elucidated with reference to the annexed drawings. Herein:

Fig. 1 shows a perspective partial view of a heat exchanger according to the invention, wherein the
15 housing is not shown for the sake of clarity;

Fig. 2a shows a schematic perspective view on small scale of a heat exchanger according to the invention with a housing and interlacing units and manifolds;

Fig. 2b shows the detail II of Fig. 2a on a larger
20 scale;

Fig. 3 is a schematic representation of an alternative offset arrangement of the fins;

Fig. 4 is a schematic representation of an unreinforced membrane;

25 Fig. 5 shows a partly broken away perspective view of a membrane reinforced with a fibre fabric;

Fig. 6 shows a view corresponding with Fig. 5 of a membrane reinforced with a non-woven material;

Fig. 7a and 7b show respective phases of adhesion
30 of the contact surfaces of fins to a membrane;

Fig. 8 shows an alternative method of adhesion;

Fig. 9a shows a cross-section corresponding with Fig. 8 of an alternative form;

Fig. 9b is a perspective view of the preliminary
35 stage of the structure according to Fig. 9a;

Fig. 10a and 10b show views corresponding with Fig. 7a and 7b respectively of an embodiment in which the fins are coupled directly to each other via holes in the membrane;

40 Fig. 10c is a perspective view of the phase shown in Fig. 10a and corresponding with Fig. 9b;

Fig. 11 shows the preliminary stage of an embodiment in which the membrane is provided on both sides with an adhesive layer;

Fig. 12 is a view corresponding with Fig. 11 of an embodiment in which the contact surfaces of the fins are provided with a coating;

Fig. 13a shows a highly schematic view of a device for manufacturing a heat exchanger according to the invention in industrial manner;

Fig. 13b shows detail XIII of Fig. 13a on enlarged scale;

Fig. 13c shows a perspective view in slightly further developed and detailed form of the device of Fig. 13a;

Fig. 14 shows a cross-sectional view of a part of a heat exchanger according to the invention during the production stage, wherein the membranes are fixed under tensile stress by means of tensioning means;

Fig. 15 shows a front view of a heat exchanger, wherein the fins and the medium circuits are ordered in a first arrangement;

Fig. 16 shows a view corresponding with Fig. 15, wherein the fins and the medium circuits are ordered in a second arrangement; and

Fig. 17 shows a cross-sectional view of alternative tensioning means.

Fig. 1 shows a heat exchanger 1, comprising a number of layers of foil 2, between which extend respective strips 3, 4, 5, 6, 7, 8 and so on. These strips 3-8 form heat-conducting fins and are manufactured for this purpose from for instance copper. By means of means to be described hereinbelow the fins are adhered with their mutually facing contact surfaces to foils 2 on either side of these foils 2. In this embodiment the successive foil layers alternately bound a primary and a secondary circuit, designated in the figure with arrows P and S respectively. These medium circuits relate to the flow of media for placing in heat-exchanging contact with each other, for instance gaseous media, liquid media or respectively gas and liquid or two-phase media.

The drawing further shows that strips 3, 4, 5 have a limited length in the medium flow direction and that the subsequent fin strips 6, 7, 8 are placed at a distance. This enhances the effective heat transfer. The intermediate space 9, which is not provided with fins, acts effectively as thermal separation in the transport direction. A prerequisite herefor is that the foil material has a limited heat conductivity and is for instance not manufactured from a good heat-conducting material such as copper. Plastic is for instance a very suitable choice. Because the foils are embodied as membranes and are therefore very thin, they present only a negligible thermal resistance at the position of the heat-transferring contact surfaces of the fins directed toward each other.

Fig. 2 shows a heat exchanger 10 which is constructed on the basis of the above described membrane-fin-heat exchanger, wherein use is made of a housing. Connecting to the free ends are respective interlacing units and manifolds 12 for P in, 13 for P out, 14 for S in and 15 for S out.

Fig. 2b shows the interior of heat exchanger 10. This is essentially the same unit as in Fig. 1 and is therefore also designated with reference numeral 1.

Fig. 3 shows very schematically an alternative arrangement of fins in respective strips 16, 17, 18, 19, 20, 16. It will be apparent that the fins are offset $1/5$ the pitch distance at a time in transverse direction relative to flow direction 21. The front edge of each fin is hereby always situated in a practically undisturbed flow. This enhances the heat transfer.

Fig. 4 shows a membrane 22 schematically.

Fig. 5 shows a membrane 23 which is reinforced with a fabric 24, for instance consisting of glass fibre, carbon fibre or the like. It is noted that the drawing is not to scale and that a mat 24 of this type can also be impregnated with a plastic, whereby the fabric is medium-tight and can moreover melt, for instance through heat, for adhering to the contact surfaces of the fins.

Fig. 6 shows a membrane 25 with a non-woven reinforcement 26.

Fig. 7a shows a membrane 28 with glue layers 29 at the position of contact surfaces 30 of fins 31. The structure drawn in Fig. 7b is obtained by pressing, wherein the glue is pressed out slightly into side zones 5 32. The glue 29 can be pre-heated or be of the pressure-sensitive type.

Fig. 8 shows an embodiment wherein fins 31 are pressed into foil 28 during heating and under pressure. The foil material is hereby made thinner in the 10 intermediate zone 33 and the material is pressed slightly outward at the side in zones 34. This embodiment is favourable in the sense that a good seal is always ensured, while the already thin foil material is made extra-thin.

Fig. 9a shows a variant in which fins 35, 36 are provided with complementary corrugations 37, 38 respectively. A good positioning of the contact surfaces is hereby always ensured. The corrugations 37, 38 also extend in transverse direction. This aspect is clearly 20 shown in Fig. 9b. Arrows 39 indicate that fins 35, 36 are forced together during heating and under pressure when foil 28 is compressed. In the embodiment according to Fig. 10 foil 40 is provided with openings 41, through which the contact surfaces of fins 31 can come into 25 mutual contact. These contact surfaces are provided with adhesive layers 42, whereby the fins can be brought into direct mutual contact via these very thin adhesive layers, as shown in Fig. 10b. Fig. 10 also shows that the peripheral edge of opening 40 is provided with a 30 mass 43 forming a sealing ring in order to ensure a medium-tight connection.

Fig. 11 shows an embodiment wherein a foil 44 is provided on both sides with an adhesive layer 45 for coupling to the contact surfaces of fins 31.

35 In Fig. 12 the contact surfaces of fins 31 are provided with adhesive layers 46.

Fig. 13 shows the manner in which the foil strips 48 and fin strips 49 adhered thereto can be assembled to form a package such as for instance drawn in Fig. 1.

40 As Fig. 13c shows, a supply container 50 contains ten supply roll 51 on which are glued foil strips with

fin strips thereon. One of the rolls, which is designated with reference numeral 52, contains only foil material 48 without fins. The diverse strips are guided together through the pinch of two guide and pressure rollers 53, 54 and fed into an electromagnetic heating device 55, whereby the hot melt present on the relevant surfaces of the foils (Fig. 11) or the contact surfaces of the fins (Fig. 12) melts, so that the desired adhesion can be realized. Inlet pressure rollers 56, 57 and 58 contribute hereto.

Fig. 13b, which corresponds with Fig. 8, shows an embodiment in which the desired adhesion has been realized by pressure and temperature increase in device 55, 56, 57, 58, 59.

Fig. 14 shows foils 60 to which fins 61 are adhered. The foils can be positioned by means of snap profiles 62, wherein it is noted that, due to the respective recess 63 and the protrusion 64 co-acting therewith, a lengthening of the foil is realized which, together with the elasticity of the foil, results in a certain bias. By stacking the profiles 62 a heat exchanger 1 of the type according to Fig. 1 or of other type can be manufactured in modular manner. The pressing direction is shown symbolically with an arrow 65. Arrow 66 designates symbolically the mobility of the foil, wherein it should be understood that during pressing as according to arrow 65 a foil is stretched and thus placed under bias.

Fig. 15 shows the structure shown in, among others, Fig. 1, wherein the primary and the secondary circuit follow each other.

Fig. 16 shows a variant in which two primary circuits are situated mutually adjacently, followed by two secondary, followed by two primary and so on.

Finally, Fig. 17 shows an alternative to the method of clamping according to Fig. 14. In the embodiment according to Fig. 17, each of the clamping blocks 62 is embodied as a generally U-shaped profile 67 with an opening 68 narrowing to the outside in which is situated a roller 70 loaded by a compression spring. According to arrow 71 a foil strip 60 can be inserted into the pinch

between the lower surface 71 of opening 68 and roller 70. While a slight pressure is exerted counter to the spring pressure of spring 69 the leading edge of foil 60 can hereby pass over the contact surface between surface 5 71 and roller 70. This arrangement takes place with some force, whereby the foil is slightly stretched until the required bias is achieved. The foil is then released and held fixedly in said pinch. This ensures a permanent bias.

CLAIMS

1. Heat exchanger, comprising
two sets of medium through-flow channels which are
placed mutually interlaced and through which two media
can flow physically separated from each other in a
primary circuit (P) respectively a secondary circuit (S)
5 and solely in heat-exchanging contact;
walls separating said channels;
heat-conducting fins which are arranged on both
sides of each wall, which fins extend with their main
planes in the respective flow directions of said media,
10 wherein a fin on the one side of a wall, via a contact
surface in the main plane of the wall in question and
forming part of the fin, is in thermal contact with a
similar contact surface of a fin on the other side of
this wall;
15 a housing in which the channel-bounding walls with
the fins are accommodated, to which housing two inlets
and two outlets for the two sets of channels connect
either individually per channel or commonly for the sets
of channels via respective manifolds,
20 characterized in that
the walls are embodied as membranes and the fins
are embodied as heat-transferring, for instance metal
strips with a general wave shape, which fins are
provided with contact surfaces connected to the walls
25 and main planes extending between two walls,
this such that, in addition to a thermal function,
the fins also have a structural function,
wherein the coefficient of heat transfer of the
whole separating wall amounts to a minimum of $1 \text{ W/m}^2\text{K}$.
30 2. Heat exchanger as claimed in claim 1,
characterized in that
corresponding contact surfaces are in thermal
contact via the wall.
3. Heat exchanger as claimed in claim 2,
35 characterized in that

the contact surfaces are adhered to the wall by means of an adhesive layer applied to at least one contact surface.

4. Heat exchanger as claimed in claim 2,
5 characterized in that
corresponding contact surfaces are directly connected to each other via a perforation in the wall by means of an adhesive layer applied to at least one contact surface.

10 5. Heat exchanger as claimed in claim 1,
characterized in that
the housing is form-retaining and the walls are connected to the housing in manner resistant to tensile stress, such that the tensile stresses occurring in the
15 walls as a result of a pressure difference between the two sets of channels can be absorbed by the housing.

6. Heat exchanger as claimed in claim 1,
characterized in that
the walls are biased such that, at a preselected
20 maximum permissible pressure difference between the two sets of medium through-flow channels, the bending of the wall between the free space defined by the contact surfaces of the fins, i.e. the bending of the membrane occurring at the relevant pressure divided by the
25 relevant mutual distance between the contact surfaces in question, amounts to a maximum of 2.5%.

7. Heat exchanger as claimed in claim 2,
characterized in that
the thermal resistance of the foil transversely of
30 its main plane amounts to a maximum of 0.1 of the thermal resistance in the case of direct contact between contact surfaces directed toward each other, and is therefore negligible.

8. Heat exchanger as claimed in claim 1,
35 characterized in that
the thermal resistance of the foil in its main plane over the mutual distance between two fins adjoining in flow direction is at least 10 times greater than in the case of fins directly coupled to each other
40 thermally.

9. Heat exchanger as claimed in claim 1,

characterized in that

the walls consist of PET, for instance reinforced PET, are treated with a corona discharge, are then provided with a primer, followed by a glue layer for
5 connection to the contact surfaces of the fins.

10. Heat exchanger as claimed in claim 1,
characterized in that

the walls consist of PVC and that the fins are connected to the walls by an ultrasonic treatment or a
10 thermal treatment, in combination with pressure.

11. Heat exchanger as claimed in claim 1,
characterized in that

the foil consists of a fibre-reinforced material, which fibres consist for instance of glass, boron,
15 carbon.

12. Heat exchanger as claimed in claim 1,
characterized in that

the walls consist of a plastic in which aluminium powder is embedded.

20 13. Heat exchanger as claimed in claim 1,
characterized in that

the wall or the glue layer optionally applied thereto as according to claim 9 is conditioned so as to obtain a property from the group to which belong:

25 - antibacterial properties
- anti-adhesion properties to repel fouling and other growth
- antistatic properties
- surface tension-changing, which conditioning can for
30 instance be applied by immersion or spraying with a suitable agent.

14. Heat exchanger as claimed in claim 1,
characterized in that

the walls protrude outside the fins such that they
35 can be connected to a frame, for instance in order to place them under bias, or such that the protruding wall parts can be thermally formed into interlacing units and manifolds for respectively joining together and separating again the sets of channels.

40 15. Heat exchanger as claimed in claim 1,
characterized in that

the heat exchanger is given a modular structure with blocks which can be releasably coupled to each other.

16. Heat exchanger as claimed in claim 1,
5 characterized in that
the layers are ordered in the sequence P, S, P, S, P, S and so on.

17. Heat exchanger as claimed in claim 1,
characterized in that
10 the layers are ordered in the sequence P, P, S, S, P, P and so on.

18. Heat exchanger as claimed in claim 1,
characterized in that
the contact surfaces of the fins have rounded
15 peripheral edges.

19. Heat exchanger as claimed in claim 11,
characterized in that
the fibres have an anisotropic heat conduction,
such as carbon fibres, wherein the heat conduction is
20 smaller in the main plane of the foil than in transverse direction thereof.

20. Heat exchanger as claimed in claim 3 or 4,
characterized in that
the adhesion has taken place with an anticorrosive
25 coating applied to at least one of the two contact surfaces and for instance comprising a primer layer and/or an adhesive layer extending over the whole surface of the fins and optionally the wall.

21. Heat exchanger as claimed in claim 3 or 4,
30 characterized in that
the adhesive layer is of the type which can be thermally activated and that the fins are adhered to the relevant wall and/or to fins located opposite thereto at the position of the contact surfaces by heating and
35 pressure by means of a heated pressing punch.

22. Heat exchanger as claimed in claims 20 and 21,
characterized in that
the fins are provided on the side remote from said coating with a second coating which can withstand said
40 heating and pressure.

23. Method for manufacturing a heat exchanger as claimed in claim 1, comprising

two sets of medium through-flow channels which are placed mutually interlaced and through which two media
5 can flow physically separated from each other in a primary circuit (P) respectively a secondary circuit (S) and in heat-exchanging contact;

walls separating said channels;

heat-conducting fins which are arranged on both
10 sides of each wall, which fins extend with their main planes in the respective flow directions of said media, wherein a fin on the one side of a wall, via a contact surface in the main plane of the wall in question, is in thermal contact with a similar contact surface of a fin
15 on the other side of this wall;

a housing in which the channel-bounding walls with the fins are accommodated, to which housing two inlets and two outlets for the two sets of channels connect either individually per channel or commonly for the sets
20 of channels via respective manifolds,

wherein the walls are embodied as membranes, and

the fins are embodied as metal strips with a general wave shape with contact surfaces connected to the walls and main planes extending between two walls,
25 this such that, in addition to a thermal function, the fins also have a structural function,

comprising the steps of

(a) providing a number of metal strips with a general wave shape;

30 (b) providing a number of widths of membrane material; and

(c) feeding these strips and widths into a connecting device in register and in alternating relationship and mutually connecting thereof to form a
35 package by means of this device.

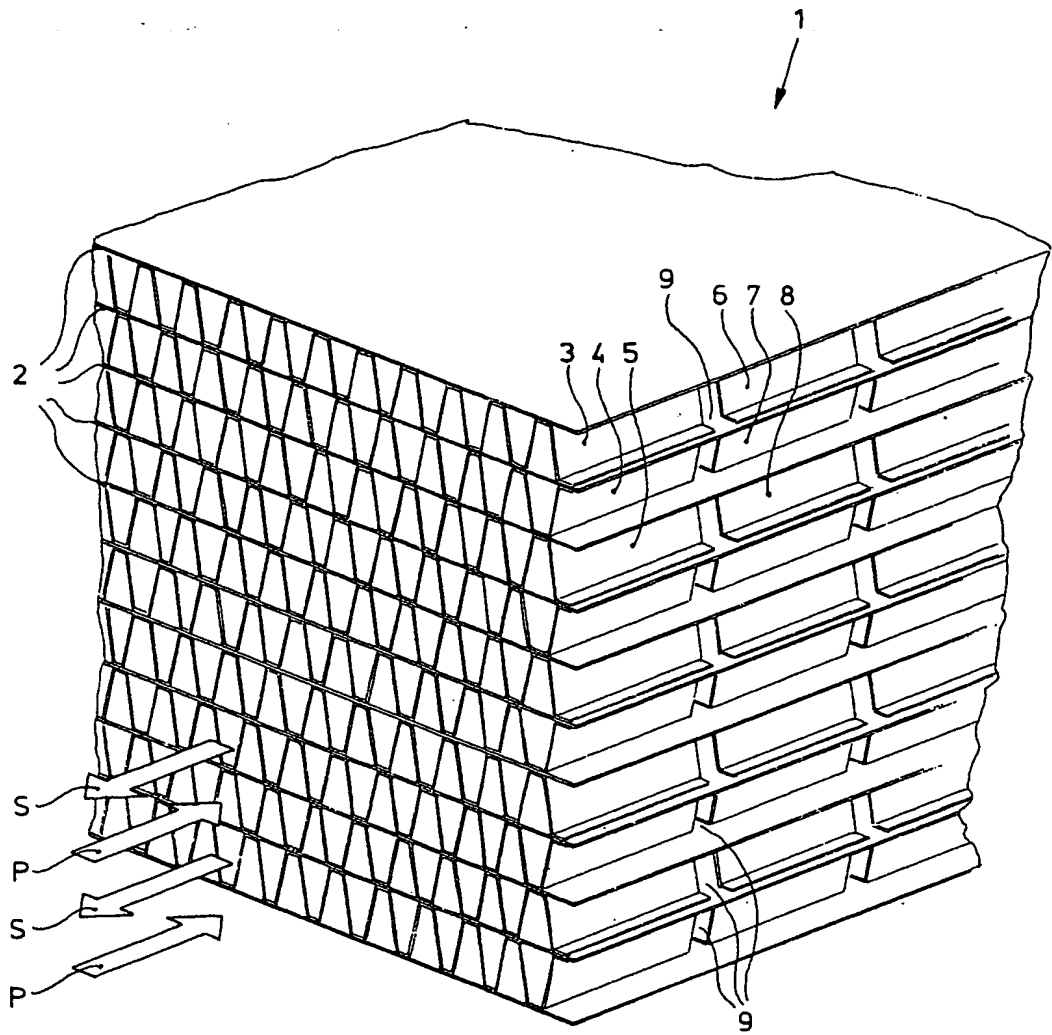


fig. 1

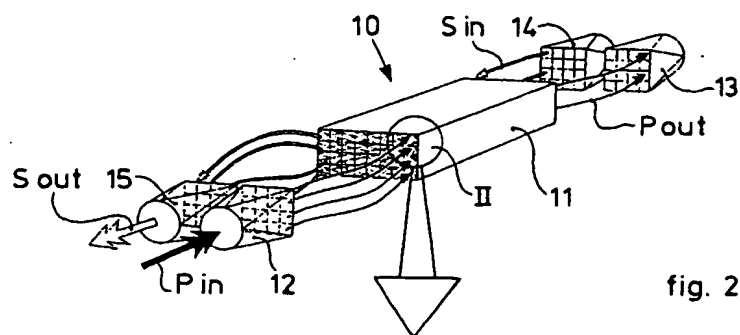


fig. 2a

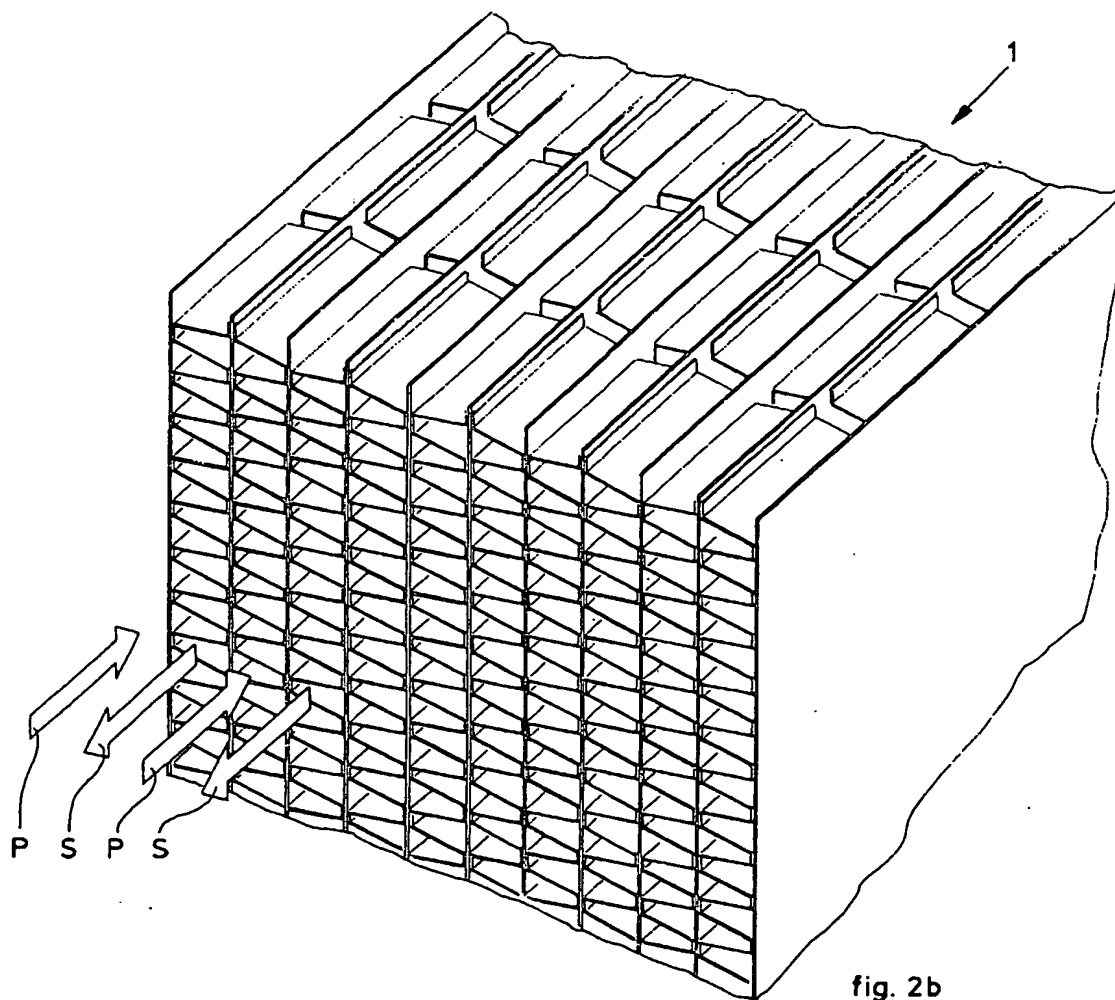


fig. 2b

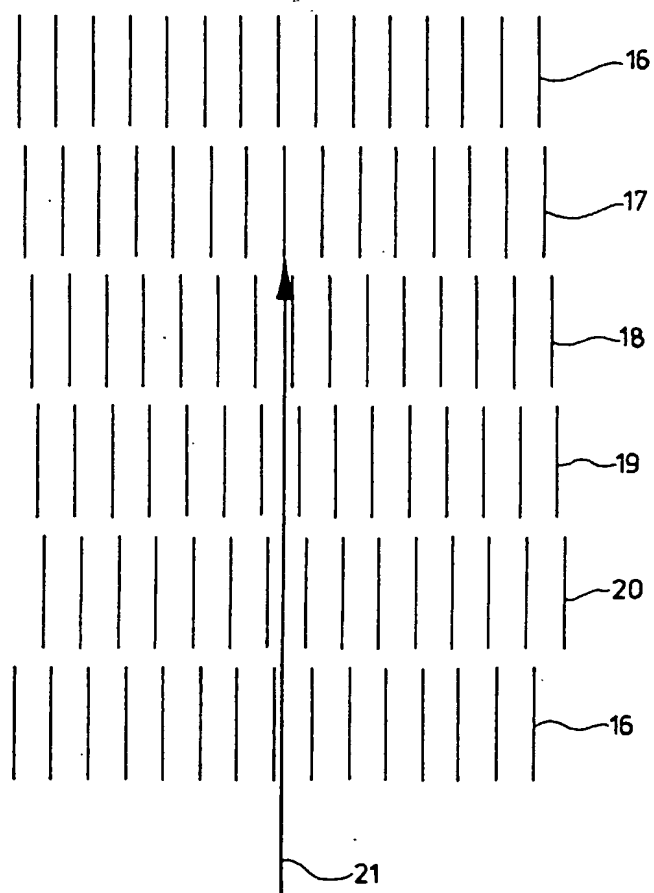
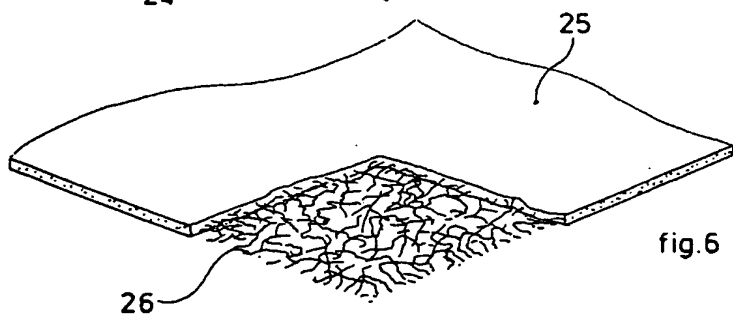
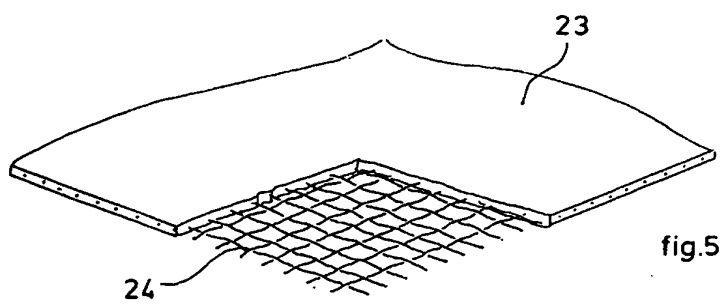
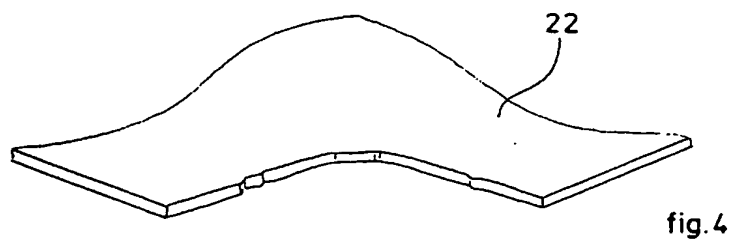


fig. 3



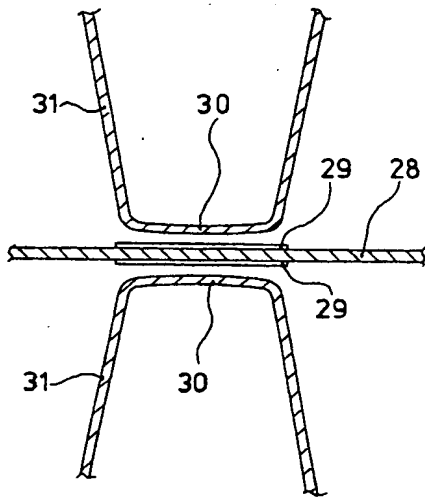


fig. 7a

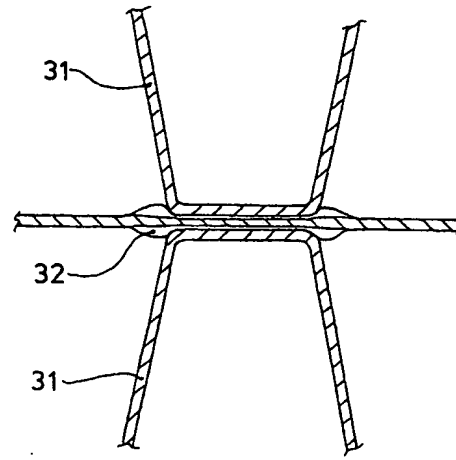


fig. 7 b

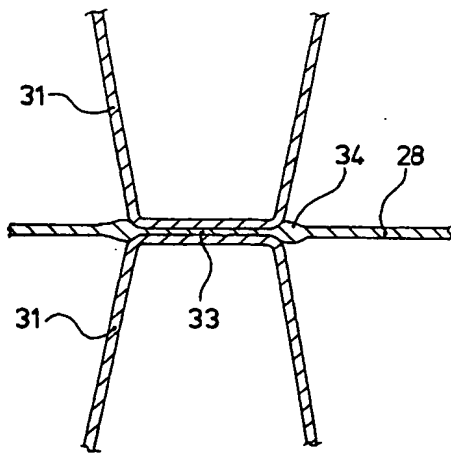


fig. 8

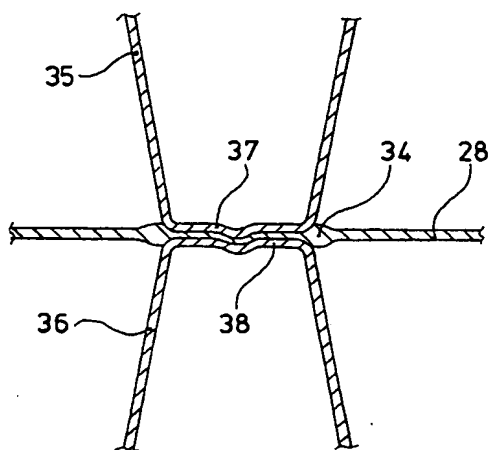


fig. 9a

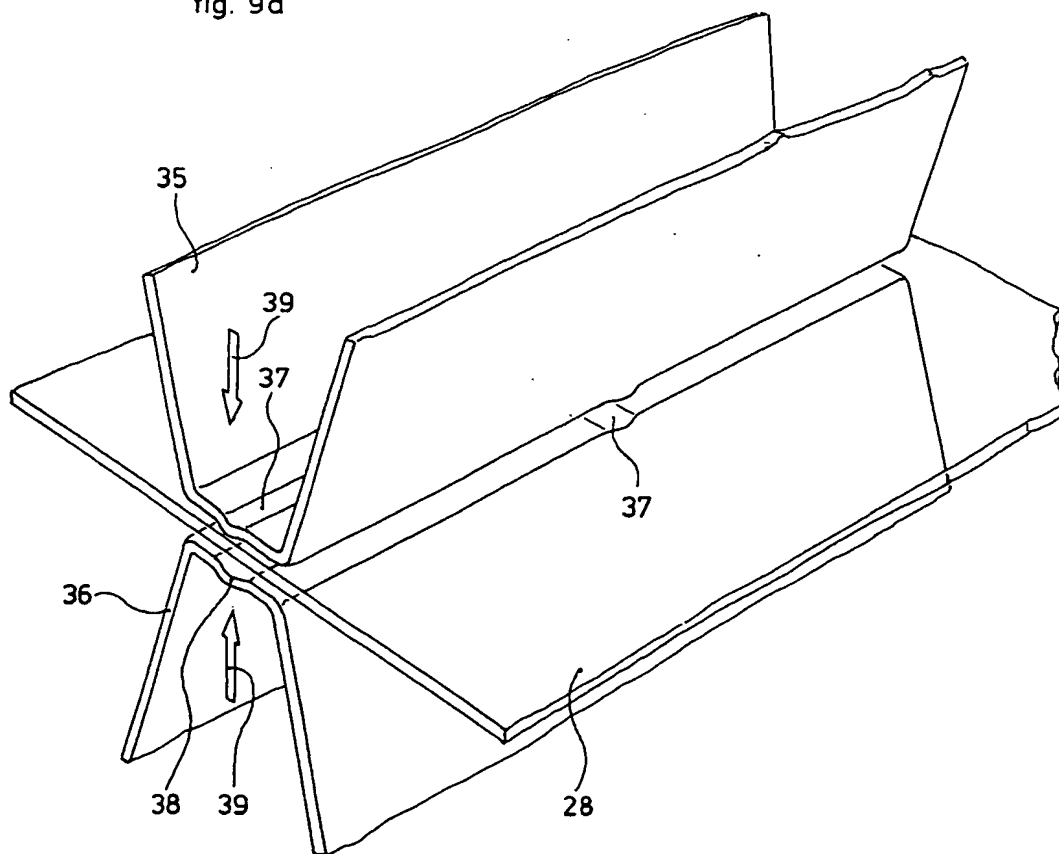


fig. 9b

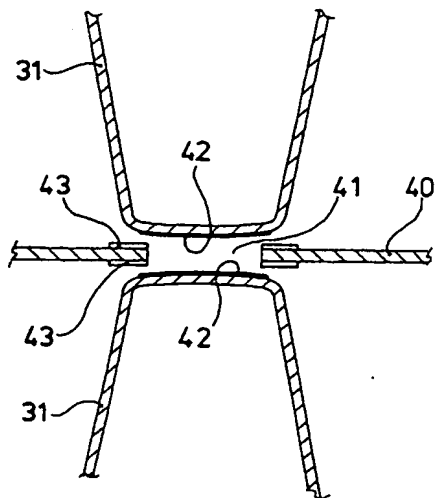


fig. 10a

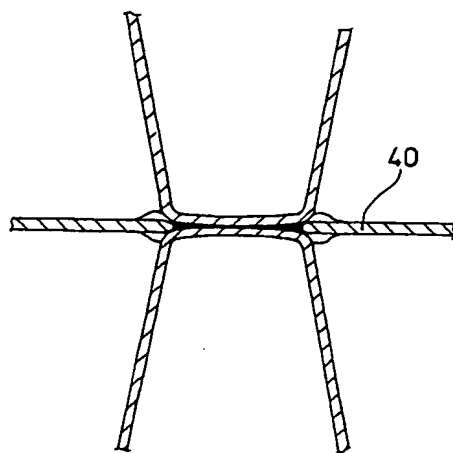


fig. 10b

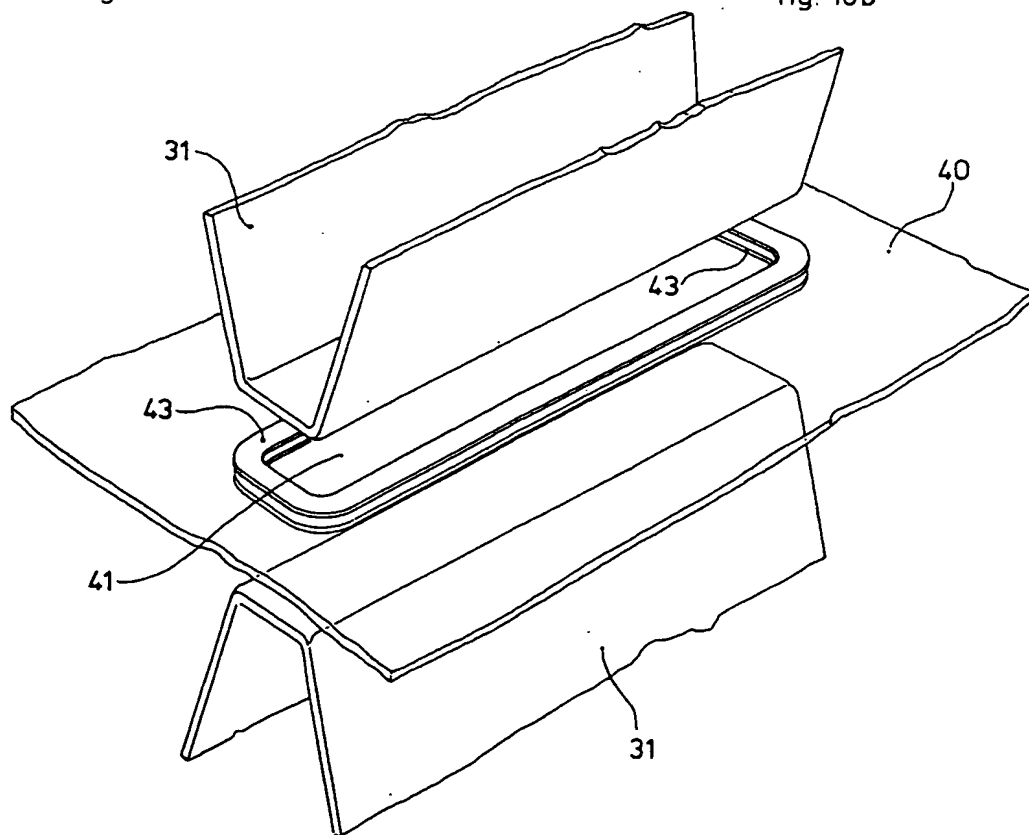


fig. 10c

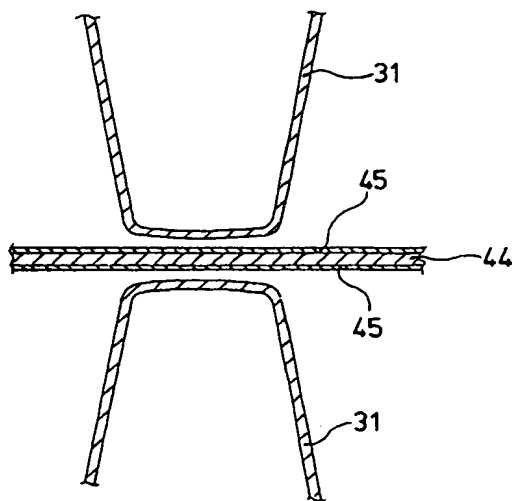


fig.11

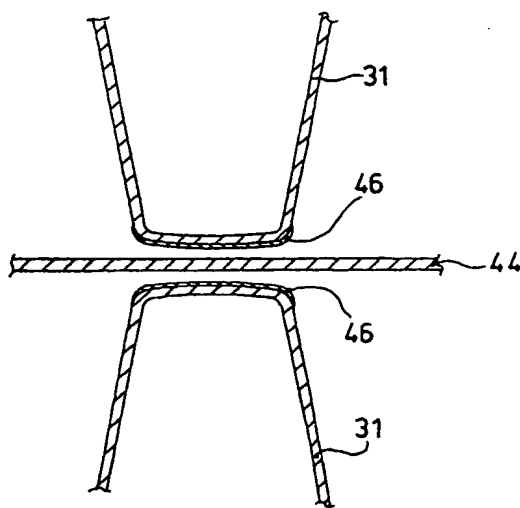


fig.12

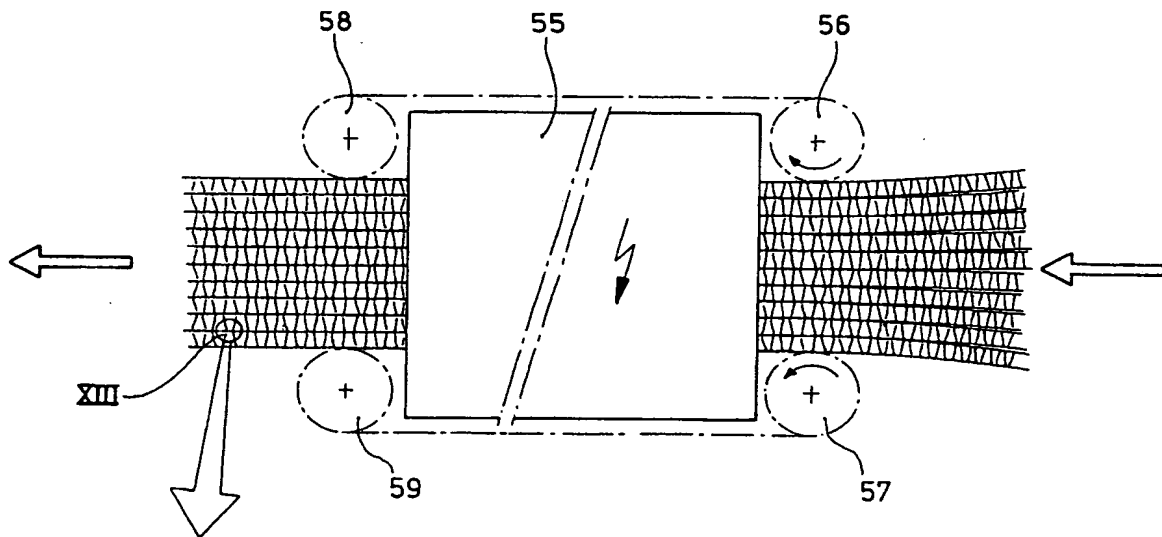


fig.13a

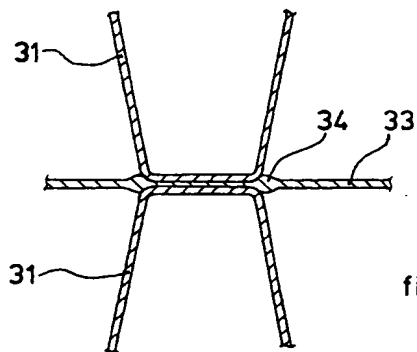


fig.13b

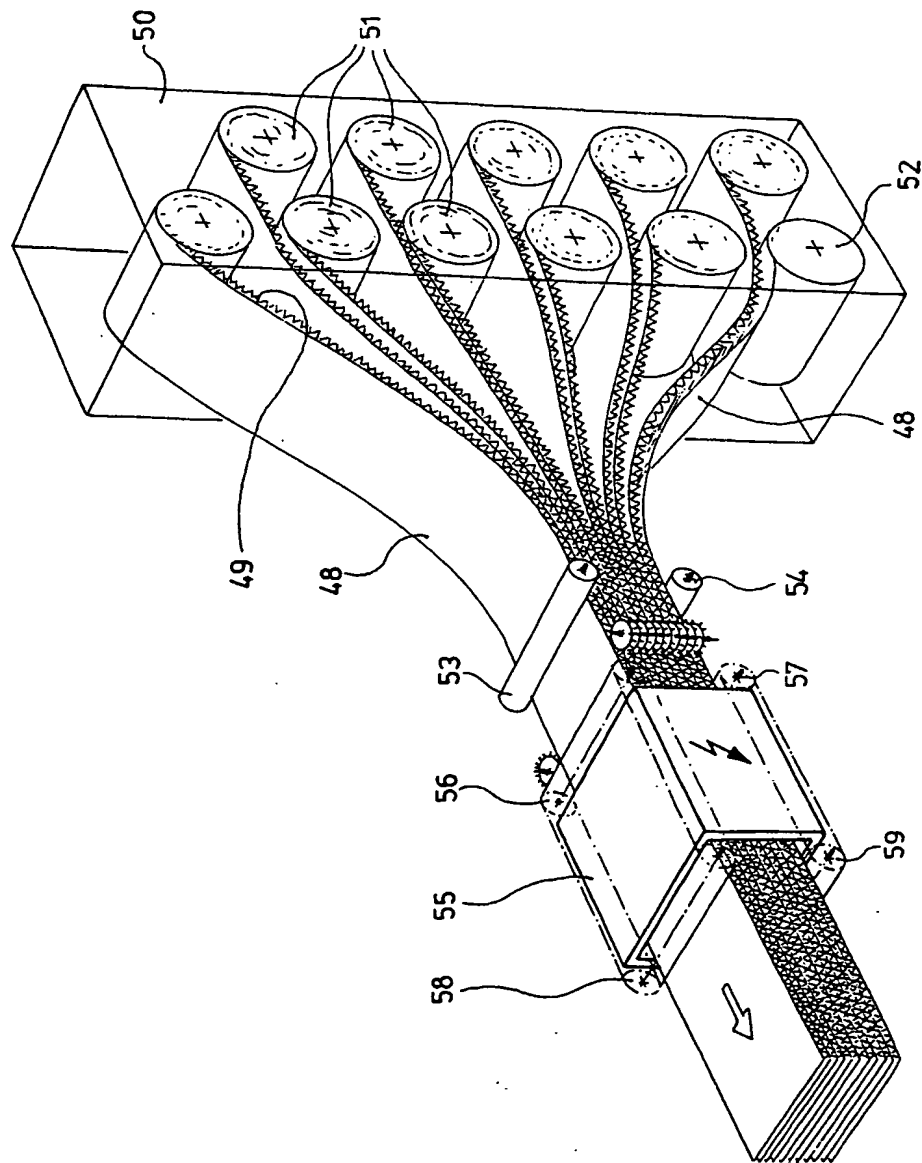


fig. 13c

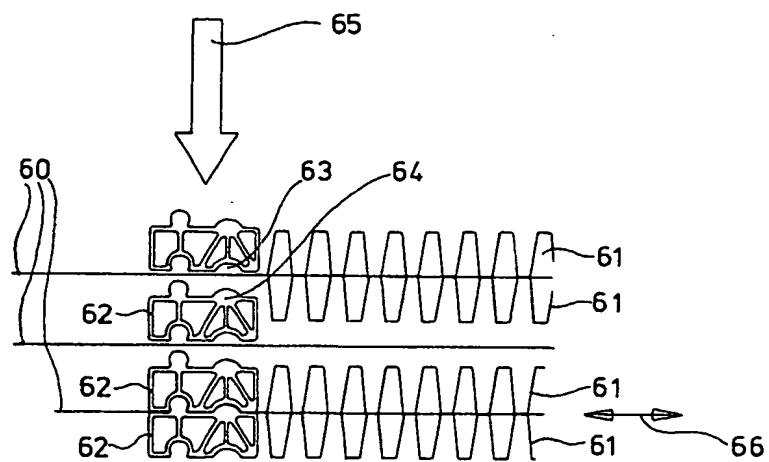


fig.14

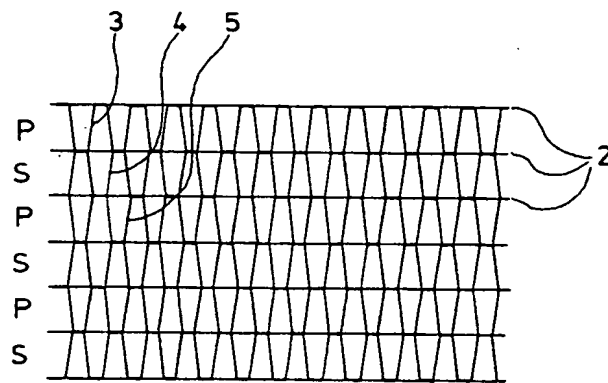


fig.15

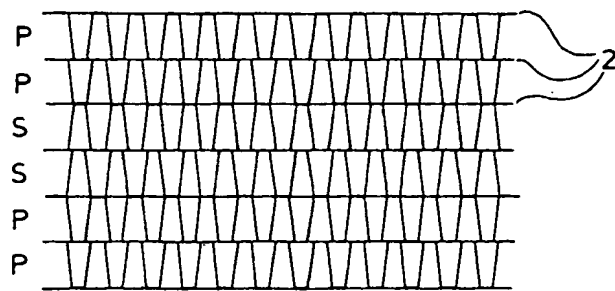


fig. 16

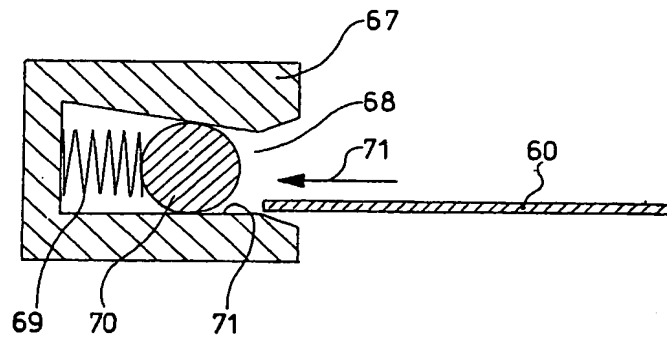


fig.17

INTERNATIONAL SEARCH REPORT

Internal Application No

PCT/NL 03/00151

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F28D9/00 F28F3/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 F28D F28F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	---	3,6,14
Y	GB 2 197 450 A (PENTAGON RADIATOR) 18 May 1988 (1988-05-18) page 1, line 86 -page 2, line 21; figures 1,2	3
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A.	---	
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Date of the actual completion of the International search

17 June 2003

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